An AI-Driven Radiation Therapy Workflow Management Platform

Doori Rose[1], Grace Chow[1], Laura I. Cervino[1], Joseph O. Deasy[1], Sharif F. Elguindi[1], Gregory Niyazov[1], Jean M. Moran[1], Darian Pazgan-Lorenzo[1], Ellen Pinto[1], Lakshmi Santanam[1], Niral M. Shah[1], Pengpeng Zhang[1], Anyi Li[1]

[1]Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, USA

Abstract Our team has engineered PlanQ, an innovative AI-powered radiotherapy workflow management platform, designed to streamline clinical decision-making and enhance operational efficiency within high-volume radiation therapy settings. PlanQ, with its flexible and modular design, integrates data across diverse systems and formats, offering real-time multimodal data curation, while incorporating practitioner insights as definitive inputs. By leveraging a sophisticated language model and natural language processing, PlanQ adeptly interlinks disparate clinical incidents, facilitates the examination of historical patient treatment information, and gauges re-irradiation hazards. Additionally, the platform centralizes the visualization and oversight of clinical workflows, and an AI-driven Operational Research model adeptly prioritizes planning schedules for a large team based on complexity and urgency. Empirical results indicate PlanQ's efficacy in diminishing coordination workload by 70%, reducing planning tasks by 10%, and saving an hour daily in plan verification efforts. The platform's language model demonstrates a remarkable 95% precision in synthesizing isolated clinical occurrences, ensuring immediate workflow transparency.

1. Introduction

A significant obstacle in radiotherapy emerges from the dispersion of patient data across disparate locations, providers, and systems. This issue is particularly pronounced within larger healthcare institutions, where crafting a digital patient profile often entails manual integration of data from numerous sources, leading to a process that's both time-intensive and susceptible to errors(Lustberg, et al. 2017).

Data on patients is frequently segmented across multiple systems. Simply amassing this data in one spot doesn't inherently synthesize a cohesive digital profile. The true utility of the data manifests when it's synthesized, reflecting the dynamic nature of a patient's health status that continuously evolves throughout their treatment. Adapting patient information in real-time to reflect these changes, and converting the data into a universally accepted format applicable for various radiotherapy scenarios(Field, et al. 2021), presents another layer of complexity.

Effective radiotherapy treatment relies on a well-orchestrated care team, where fluid communication, coordination, and immediate access to an updated digital patient profile are crucial for successful outcomes and error prevention. Real-time updates to the patient's status within their digital profile are vital for the care team to promptly adjust treatment plans. Yet, with frequent reliance on email for communication, tracking patient updates becomes challenging, particularly in high-volume settings, leading to communication overload and potential risks in patient care.

Our project introduces an AI-enabled system(Vandewinckele, et al. 2020) designed to streamline the management of radiotherapy workflows. This system forges connections between diverse clinical events and crafts a continuous digital narrative for each patient, enhancing clinical decision-making. Deployed in high-volume radiation therapy centers, the platform aims to improve workload efficiency and adapt to a broad spectrum of clinical scenarios.

2 Materials and Methods

The cornerstone of PlanQ platform is the harmonization, integration, and capturing of federated patient data to construct comprehensive digital profiles. We have developed a versatile connector layer capable of interfacing with a multitude of established vendor systems. By leveraging advanced distributed big data technologies, our system can interface with over 13 hospital-wide systems and seamlessly integrate common RT vendor systems such as MIM, Aria, and Mosaiq. Our integration process creates a robust foundation for each patient's digital profile by combining data from various modalities, including pathology and radiology reports and diagnostic and simulation DICOM images. PlanQ processes this data through a multi-stage ingestion approach, incorporating both nightly batch updates and real-time event-driven updates, ensuring that all care team members have access to the most current and comprehensive patient profiles from any location and device.

The pivotal step lies in curating the data to map out the interconnected patient journey, which is essential for clinical decision support. Our sophisticated curation engine employs patient matching, data normalization, cutting-edge medical language models, and knowledge graphs to analyze and vectorize multimodal patient data. This process includes extracting structured reports from unstructured simulation orders and prescriptions, using the widely embraced Fast Healthcare Interoperability Resources (FHIR) standards to store and standardize longitudinal patient information.

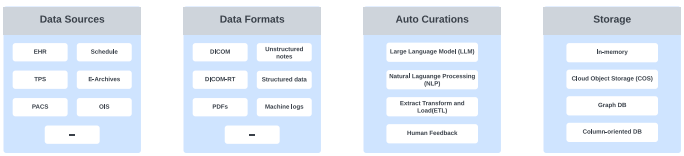

Figure 1. Highlights of PlanQ features: Its heterogeneous architecture adapts to various vendor systems and multimodality environments. The auto curation algorithms and infrastructures enable the near-real-time ingestion and curations from enterprise-wide data sources

PlanQ introduced an assistant feature that relies on expert human guidance to fine-tune the algorithm's curation process, ensuring the identification and inclusion of all relevant

patient data elements, such as historical RT treatment records, to create a high-quality digital profile. The patient events are organized into a 'subway map' visualization, providing a clear and continuous update on each treatment phase, giving the management team a comprehensive overview of clinic performance. This centralized system for documents, records, and team communication streamlines interactions and clarifies the treatment planning process.

PlaQ is built as a scalable and modular entity that accommodates data from an array of vendor systems and environments. Data curation occurs in real time, adhering to FAIR data principles, with human feedback anchoring the veracity of the curation process. Using an expansive language model and natural language processing, it connects disparate clinical events, sifts through and interprets past treatment data, and assesses the risk of re-irradiation. The platform consolidates the visualization and oversight of the clinical workflow, offering a singular, integrated viewpoint. Furthermore, we have integrated an AI-enhanced Operational Research model to refine the scheduling process, adjusting for the varying complexities and priorities within a team of 70 planners.

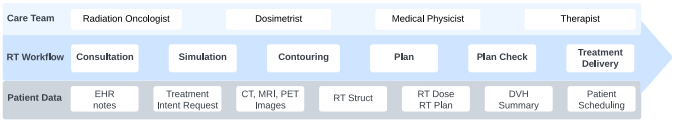

Figure 2. Disconnected patient data and communications between multiple clinical teams make RT workflow challenging. PlanQ integrates and curates data in real-time and makes the data accessible through cloud computing, improving the coordination between care teams and supporting clinical decisions

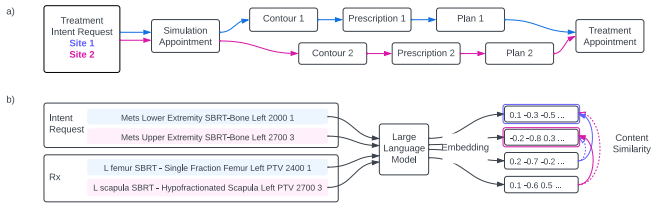

Figure 3. a) The intelligent curation module uses AI to connect the unstructured, non-standard clinical notes at the site level when multiple sites are treated at the same or different timelines.
b) We use an LLM trained in a medical knowledge base to link clinical events described with non-standardized medical terminology. We extract features from treatment intent reports and prescriptions using a sentence transformer, store the vector embeddings in an in-memory database, and calculate the vector similarities to link the evens at the site level

3 Results

Trials and implementation of PlanQ have demonstrated enhanced operational efficiency in the management of radiotherapy workflows. Notably, we have documented a 70% reduction in the effort required for treatment planning coordination, a 10% decrease in planning tasks, and a daily time saving of one hour for planning verification activities. Through PlanQ's effective data curation, retrieving historical radiation records has become more efficient, saving valuable time for physicians, planners, and physicists and reducing the risk of re-irradiation. The sophisticated Large Language Model (LLM) utilized by PlanQ exhibits a 95% accuracy level in synthesizing and associating separate clinical events, which grants immediate, real-time access to the radiotherapy planning process for all clinical teams involved. The platform's vendor-agnostic design ensures its compatibility and flexibility across a diverse array of radiotherapy workflows and clinical environments.

4 Discussion

Figure 4. Screenshots of PlanQ
a) Multiple sites treatment intents
b) Patient journey with Rx (LLM)
c) Prior irradiation records (NLP classifier)
d) DVH summary
e) Patients view from various of sources

PlanQ is an AI-enhanced, ready-for-clinic informatics platform specifically designed to streamline the complexities of managing radiotherapy workflows. PlanQ effortlessly conforms to vendor-neutral systems and multi-modality clinical settings with its versatile architecture. At its core, PlanQ constructs a comprehensive, visual timeline of each patient's treatment, anchored in the FAIR data principles, weaving together disparate data streams to aid instantaneous clinical decision-making. This integration provides a longitudinal view of the clinical workflow and detailed patient information.

PlanQ refines the accuracy of treatment plans and enhances the synergy between therapists, planners, physicists, and physicians. In essence, PlanQ not only streamlines communication but also redefines the landscape of clinical informatics, establishing a new paradigm for patient-focused radiotherapy management.

5 Conclusion

The PlanQ platform is a clinic-ready AI-driven enterprise-wide radiotherapy workflow management and clinical decision support system, showing promising results in improving efficiency and accuracy in treatment planning workflow. Its adaptability makes it a powerful and user-friendly tool to handle the complexities of radiotherapy workflows and support clinical decision-making in a variety of setups.

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